



GMPLS Module Description

ANTD. ITL. NIST

Chul Kim



Outline

- GMPLS Introduction
- What is changed
- Design and Implementation of GMPLS Functionality
- GMPLS Modules
- GMPLS Monitor Infrastructure
- Appendix
- Basic Examples

ITL Information Technology Laboratory
Advanced Network Technologies Division

NIST National Institute of Standards and Technology

GLASS Workshop - GMPLS Module, Chul Kim



GMPLS Introduction



ITL Information Technology Laboratory
Advanced Network Technologies Division

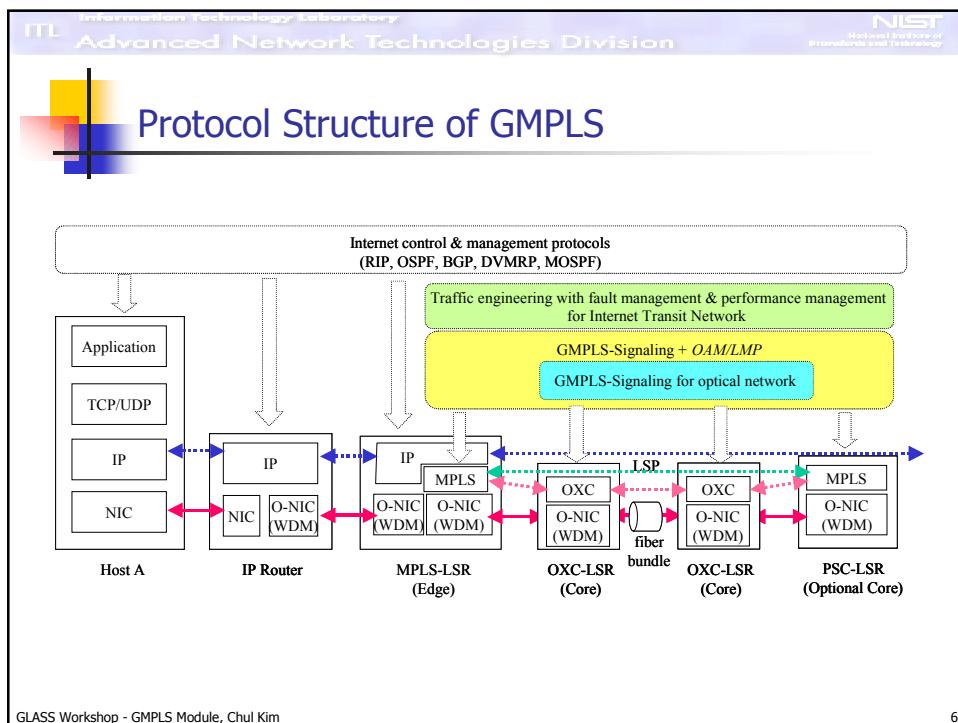
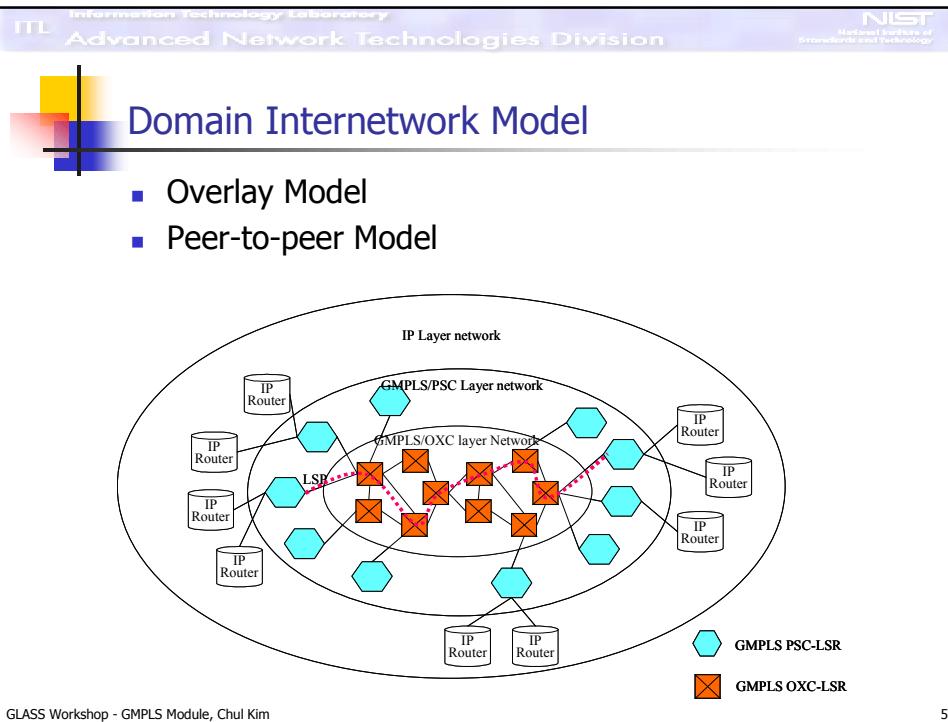
NIST National Institute of Standards and Technology

Why MPLS

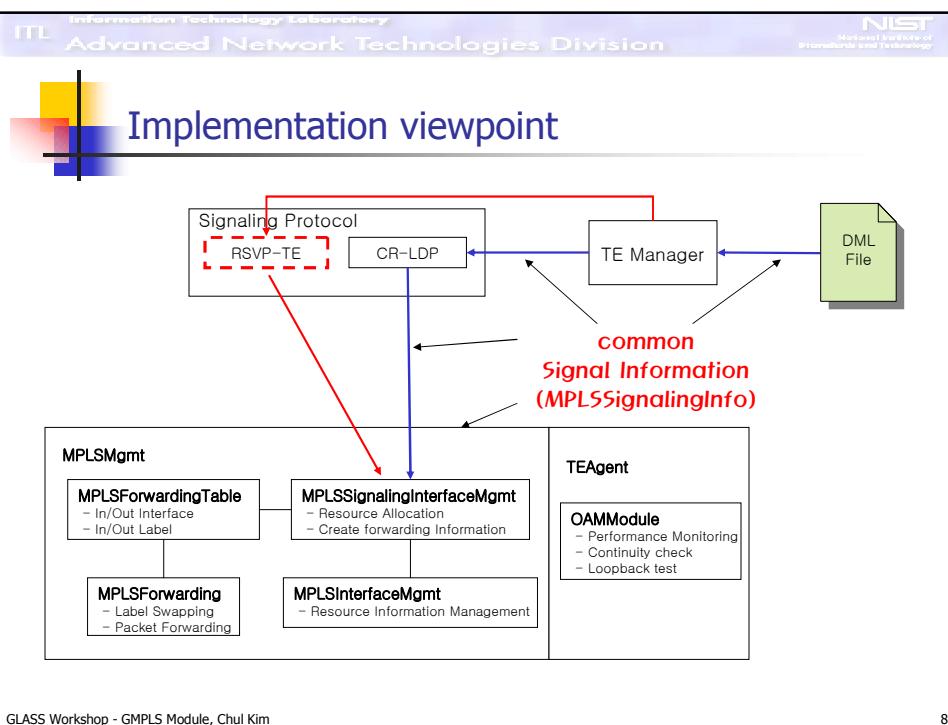
- Fast forwarding speed
- Traffic Engineering
 - Constraint-based routing
 - Explicit routing
 - Ability to reserve network resource and to modify link attributes
- Voice/Video on IP
 - Delay variation + QoS Constraints
- Virtual Private Networks
 - Controllable tunneling mechanism

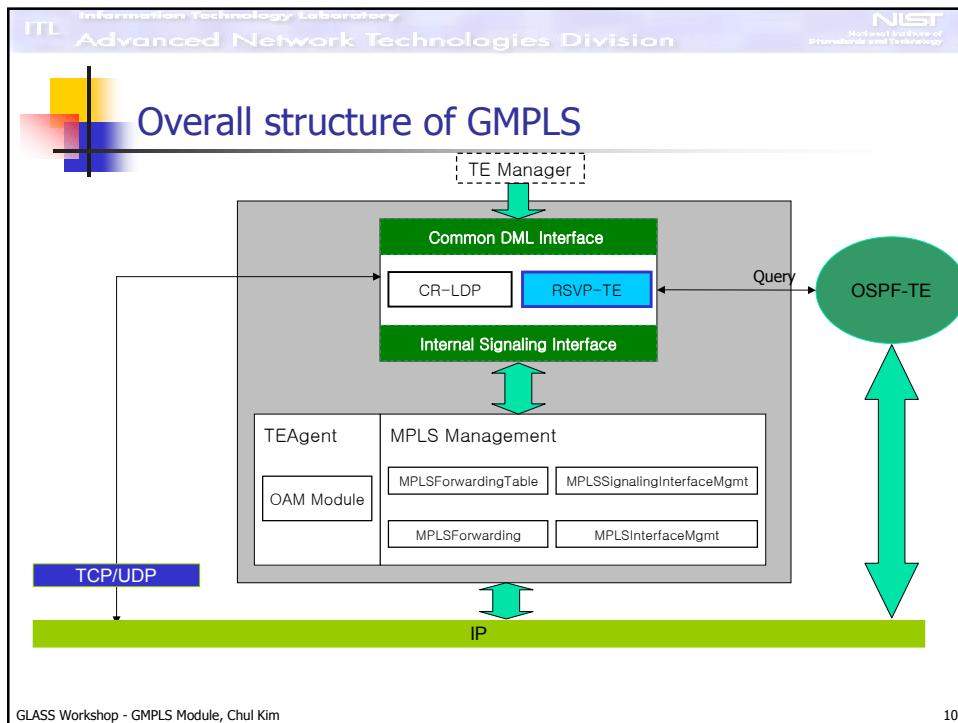
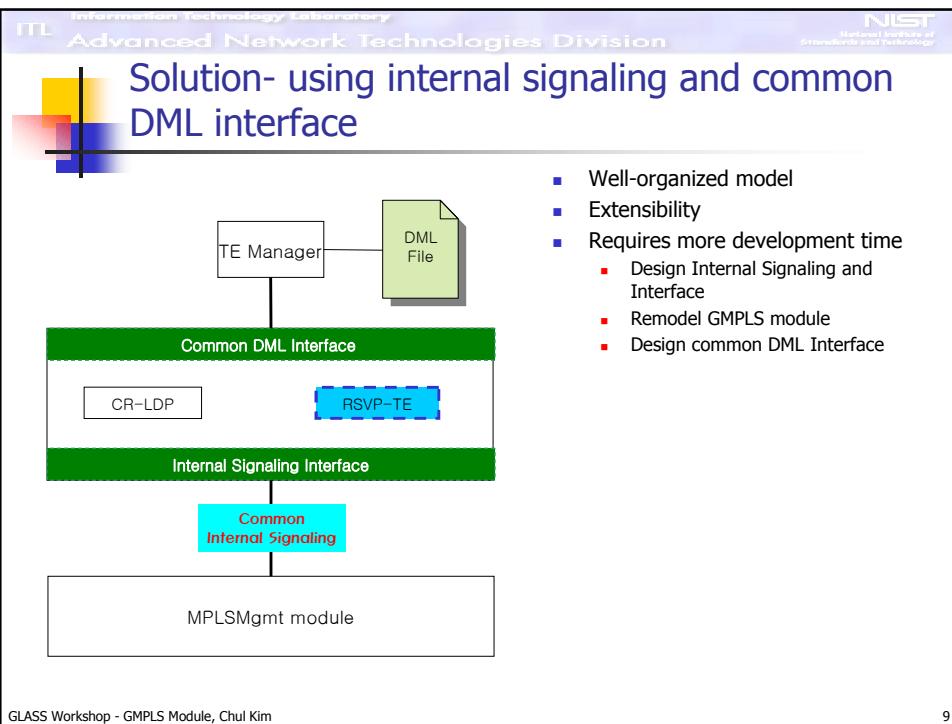
GLASS Workshop - GMPLS Module, Chul Kim

4



What is changed





Purpose of Modification

■ To integrate with RSVP-TE Signaling Protocol

- Common Signaling Information Interface
- Common DML Information Interface
- No Functional Modification
 - Rename package name
- Re-design the GMPLS modules
 - Modularization
 - Remove obsolete code/comments

Common DML Configuration Module

- Configure the LSP setup information using a DML File
- Support common LSP setup information to both signaling protocols
- Support Protocol-specified information
 - RSVP-TE
 - Reservation Style, Route Record option, Explicit Label recording option, etc.

Internal Signaling Module

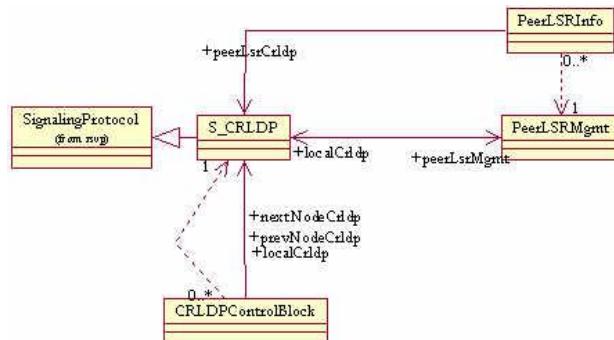
- Separate Signaling protocol from the MPLS Management module
- Support common interfaces between MPLS management module and signaling modules
- Support protocol-specified interface to perform the protocol-specified options

Modified GMPLS Module Description

CRLDP and CRLDP Control Block Module

- CRLDP Signaling Module

- Inherited from SignalingProtocol that provides common interfaces being used to request services of MPLS management module.



GLASS Workshop - GMPLS Module, Chul Kim

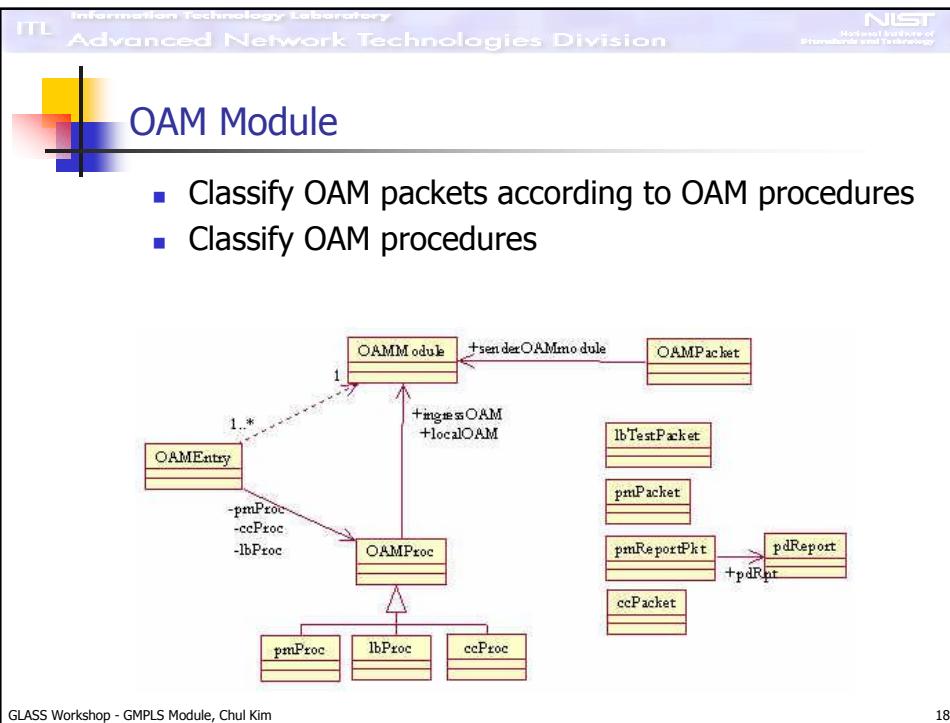
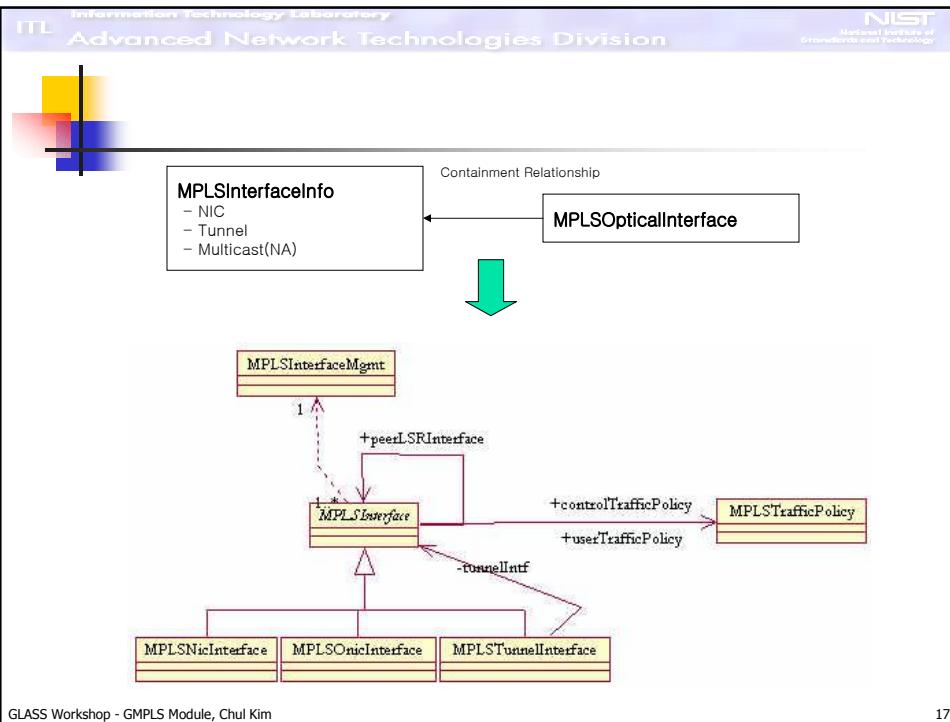
15

MPLSInterfaceInfo module

- Support data link layer's role in MPLS
- Separate interface classes according to the NIC type
- Support four kind of Interface
 - MPLSNicInterface
 - MPLSONicInterface
 - MPLSTunnelInterface

GLASS Workshop - GMPLS Module, Chul Kim

16





Modified Modules List

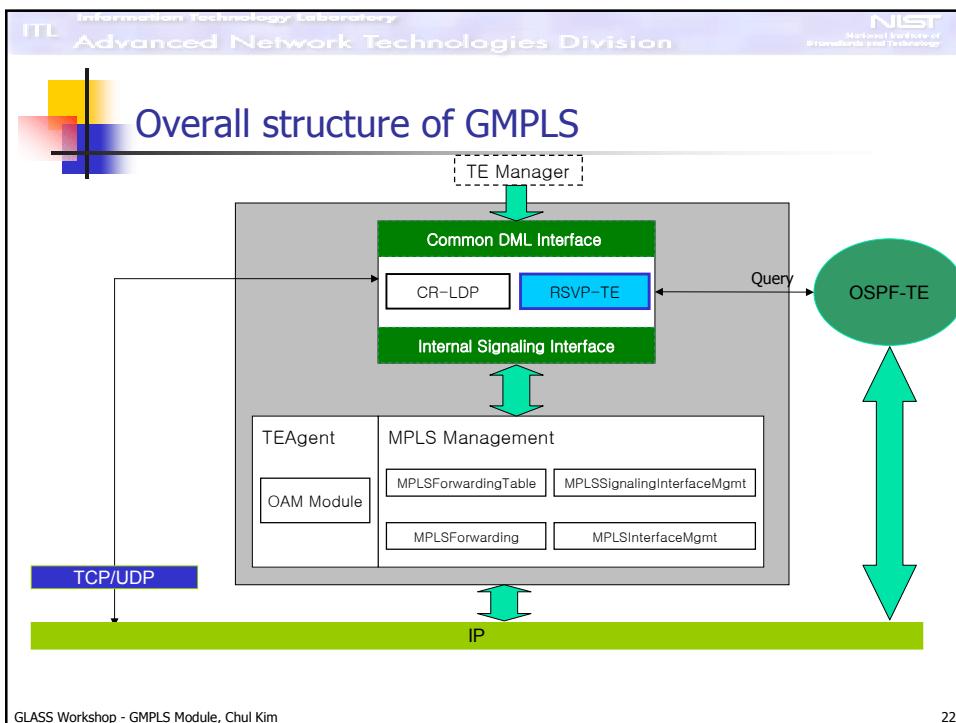
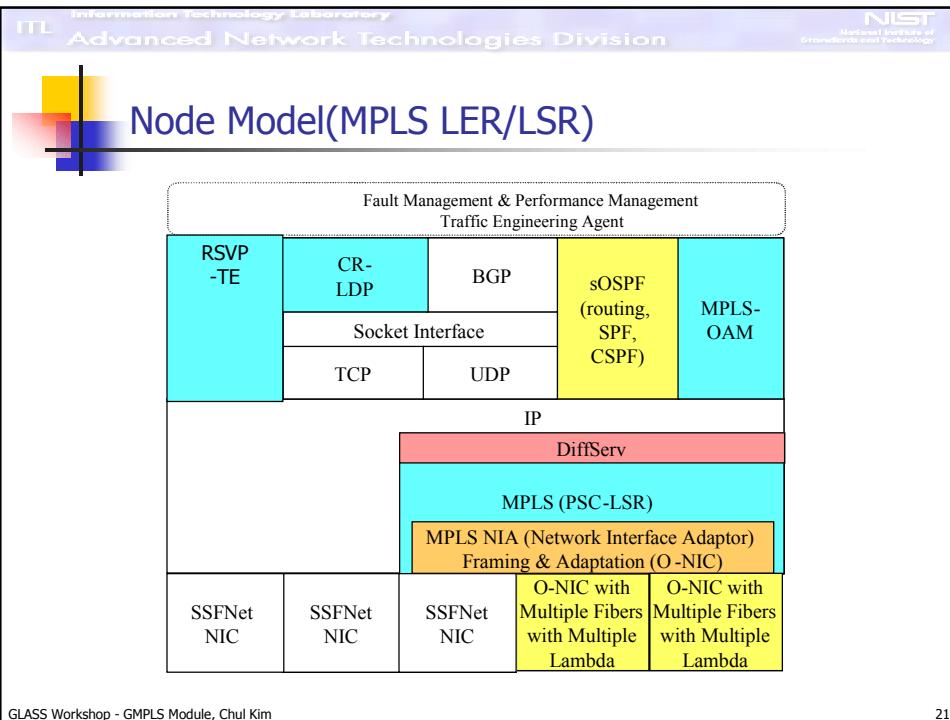
Modules	Description
S_CRLDP, CRLDPControlBlock, PeerLSRInfo, PeerLSRMgmt	Create new Package crldp under gov.nist.antd.mpls.signaling
MPLSInterfaceInfo → MPLSInterface	Rename the MPLSInterfaceInfo to MPLSInterface. Change Abstract class
MPLSNicInterface, MPLSONicInterface, MPLSTunnelInterface	Create new Interface Class based on MPLSInterface
MPLSSchedulingQueueEntry	Removed
MPLSREDQueue, MPLSDropTailQueue,	Merged to MPLSQueue
OAMModule, OMAPacket	Move to new package OAM under gov.nist.antd.mpls.mgmt
OMAEntry, OAMProc lbProc, pmProc, ccProc	Created
ccPacket, lbTestPacket, pmPacket, pmReportPkt	Created. Extract information from OAMPacket
MPLSSignalingInfo	Renamed to CRldpSigInfo
MPLSSignalingMessage	Renamed to CRldpMessage
backup_lsp_info error_param ouni_lsp_param TunnelLSPInformatiton	Created Extract from the MPLSSignalingInfo
ForwardingInformation	Change : extends from the Hashtable
SignalingProtocol	Super-class of two RSVP and SCRLDP module

GLASS Workshop - GMPLS Module, Chul Kim

19

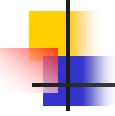


Design and implementation of GMPLS



ITL Information Technology Laboratory
Advanced Network Technologies Division

NIST
National Institute of
Standards and Technology



GMPLS Modules Design

- Based on UML
- Re-design the glass 1.0 GMPLS Modules

GLASS Workshop - GMPLS Module, Chul Kim

23

ITL Information Technology Laboratory
Advanced Network Technologies Division

NIST
National Institute of
Standards and Technology



GMPLS Functionality in GLASS

- Support two signaling protocols
 - CR-LDP, RSVP-TE
- LSP Setup/release
- Traffic Engineering
 - Explicit Route configuration
 - Constraint-based route configuration (OSPF-TE)
 - Tunnel LSP configuration
- Label Stacking
 - Tunnel LSP / Optical LSP
- Scheduling
 - Support three different types
- Queuing

GLASS Workshop - GMPLS Module, Chul Kim

24



ITL Information Technology Laboratory
Advanced Network Technologies Division

NIST National Institute of Standards and Technology

- Multi-host configuration
 - Several hosts can use one LSP
- Designate Tunnel LSP
 - LSP can specify the tunnel LSP which it goes through
- Management Modules
 - MPLS OAM functions
 - Fault Management module
 - Handling Fault and recover events

GLASS Workshop - GMPLS Module, Chul Kim

25



ITL Information Technology Laboratory
Advanced Network Technologies Division

NIST National Institute of Standards and Technology

Implemented GMPLS Modules

- GMPLS Signaling Protocol Modules
 - CRLDP
 - RSVP-TE
- MPLS Modules
 - MPLS Signaling Interface
 - MPLS Interface
 - MPLS forwarding Table
 - MPLS forwarding
- Management Modules
 - TE Agent
 - Fault Manager
 - OAM modules
- DiffServ Modules

GLASS Workshop - GMPLS Module, Chul Kim

26

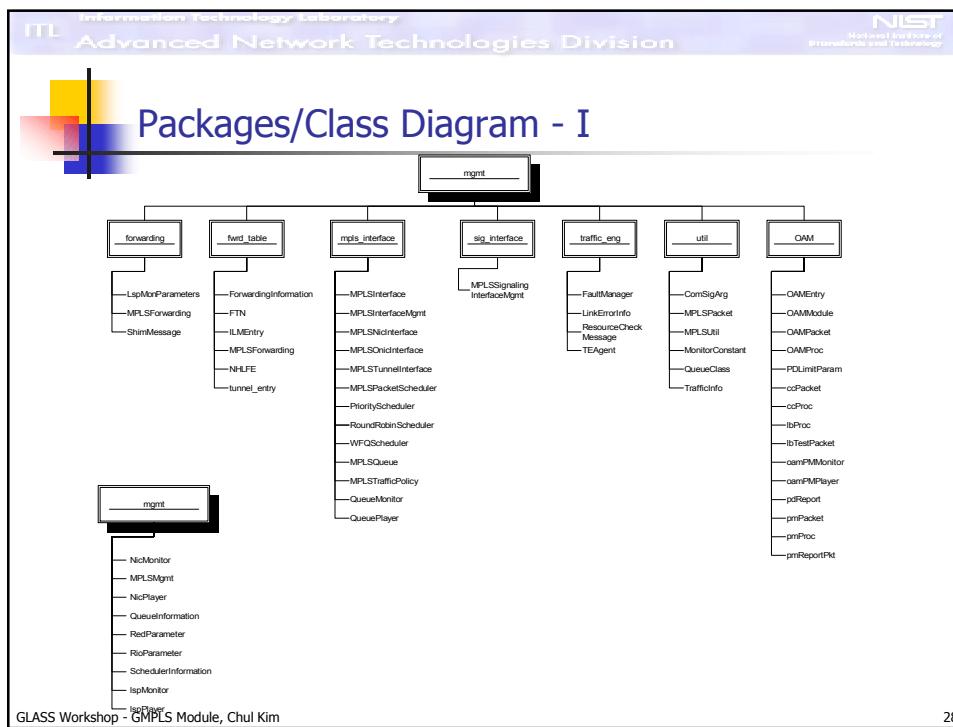
ITL Information Technology Laboratory
Advanced Network Technologies Division

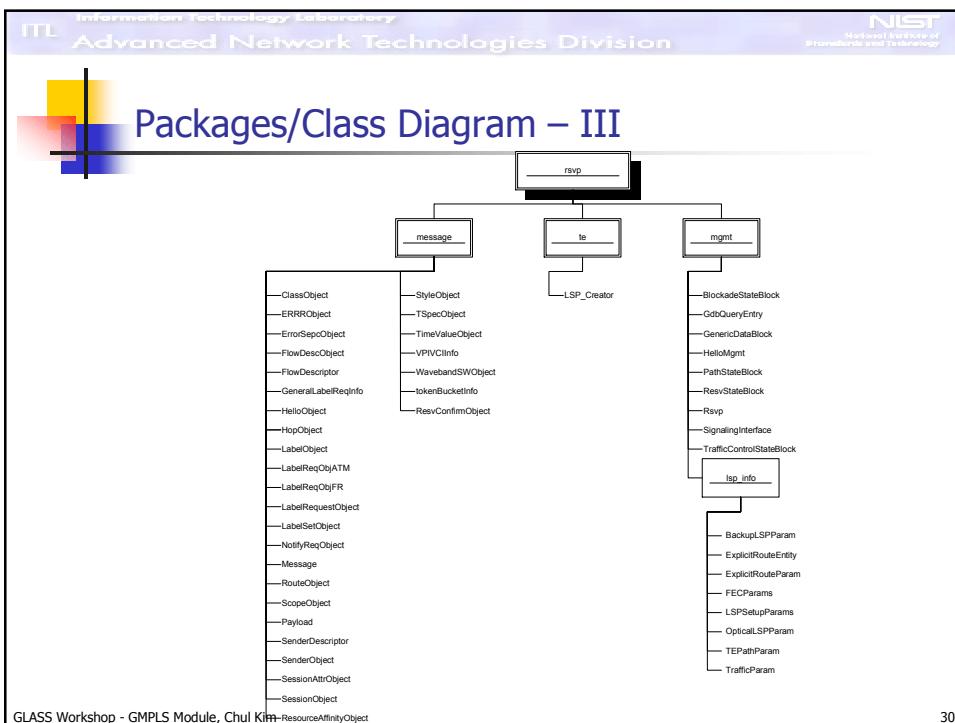
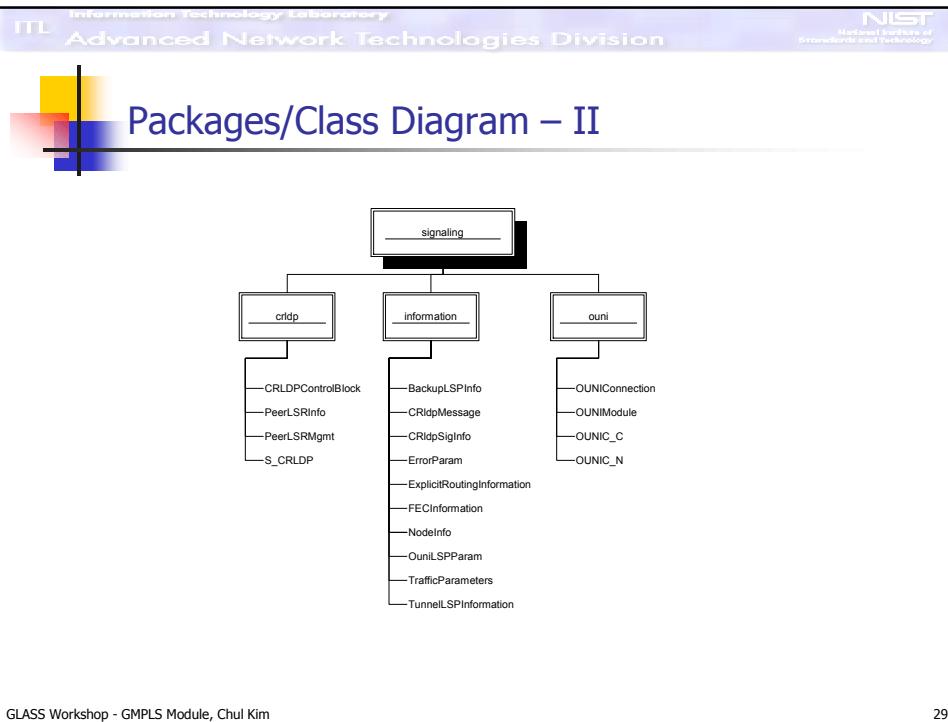
NIST National Institute of Standards and Technology

- Interface Module
 - Common Signaling Interface
 - Common DML configuration Interface
- Monitor & Player Module
 - LSP Monitor/Player
 - Queue Monitor/Player
 - OAM Performance Monitoring Monitor/Player
 - NIC Monitor/Player

GLASS Workshop - GMPLS Module, Chul Kim

27







GMPLS Modules



Modules Description with Class Diagram

ITL Information Technology Laboratory
Advanced Network Technologies Division

NIST National Institute of Standards and Technology

Signaling Protocol – Class Diagram

- SignalingProtocol module
 - provides common interfaces being used to request services of MPLS management module.

```

classDiagram
    class PeerLSRMgmt {
        +peerLSRMgmt
    }
    class PeerLSRInfo {
        +peerLSRInfo
    }
    class SignalingProtocol {
        +sigProtocol
        +peerSigProtocol
    }
    class RSVP {
        +from mgmt
    }
    class S_CRLDP {
        +from cldp
    }

    PeerLSRMgmt "1" --> "0..1" PeerLSRInfo : +peerLSRMgmt
    PeerLSRInfo "0..1" --> "1" SignalingProtocol : +peerLSRInfo
    PeerLSRInfo "0..1" --> "1" RSVP : +peerLSRInfo
    PeerLSRInfo "0..1" --> "1" S_CRLDP : +peerLSRInfo
    SignalingProtocol "1" --> "1" RSVP : +sigProtocol
    SignalingProtocol "1" --> "1" S_CRLDP : +peerSigProtocol
  
```

GLASS Workshop - GMPLS Module, Chul Kim

33

ITL Information Technology Laboratory
Advanced Network Technologies Division

NIST National Institute of Standards and Technology

sCRLDP – Class Diagram

- CRLDP Signaling Protocol

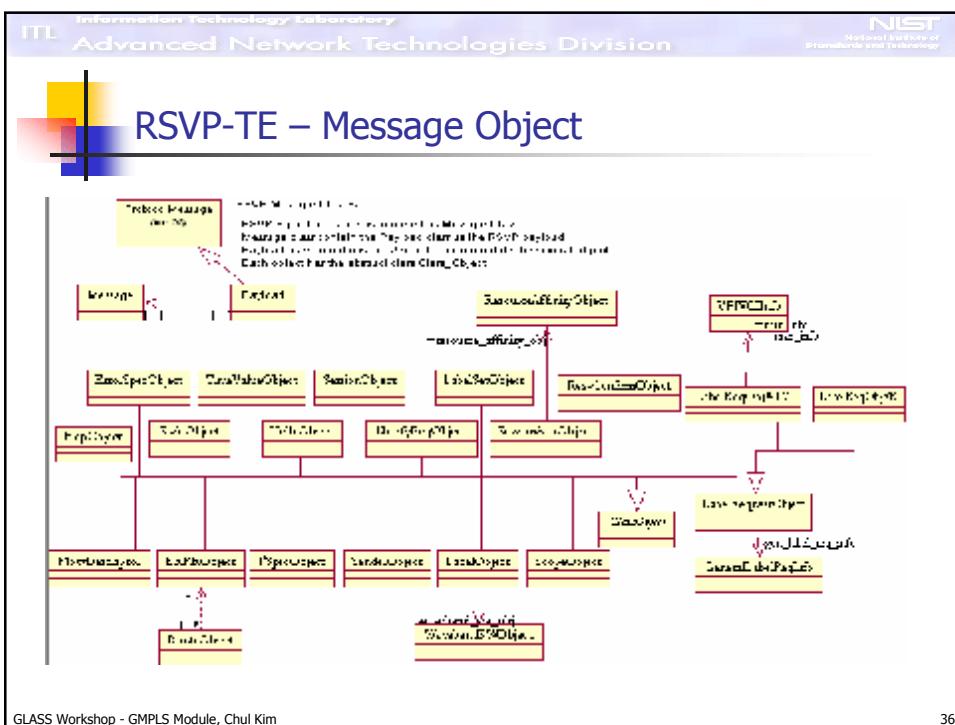
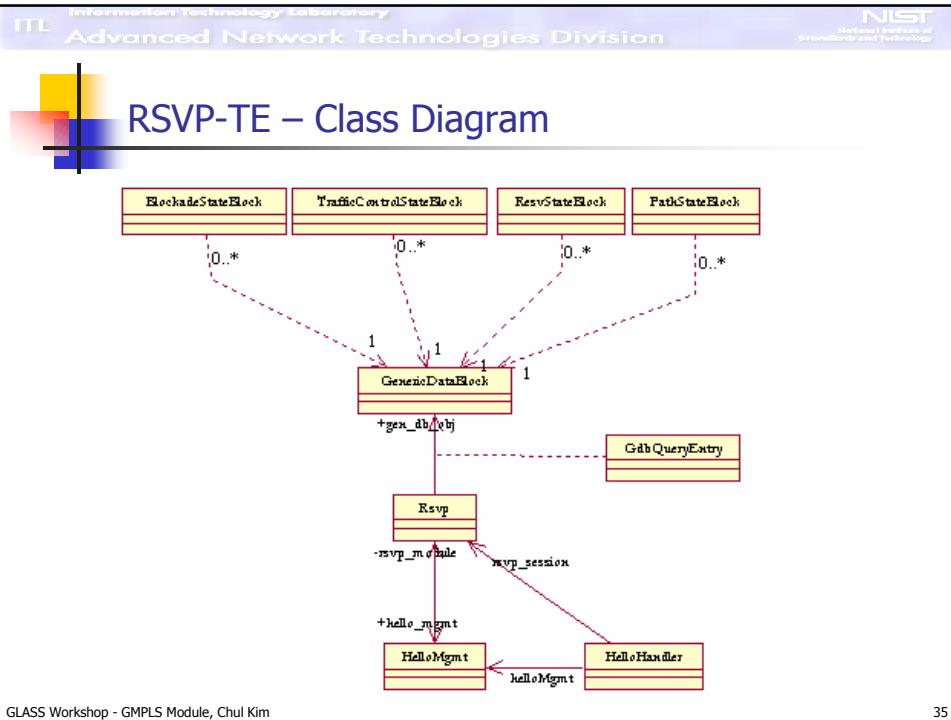
```

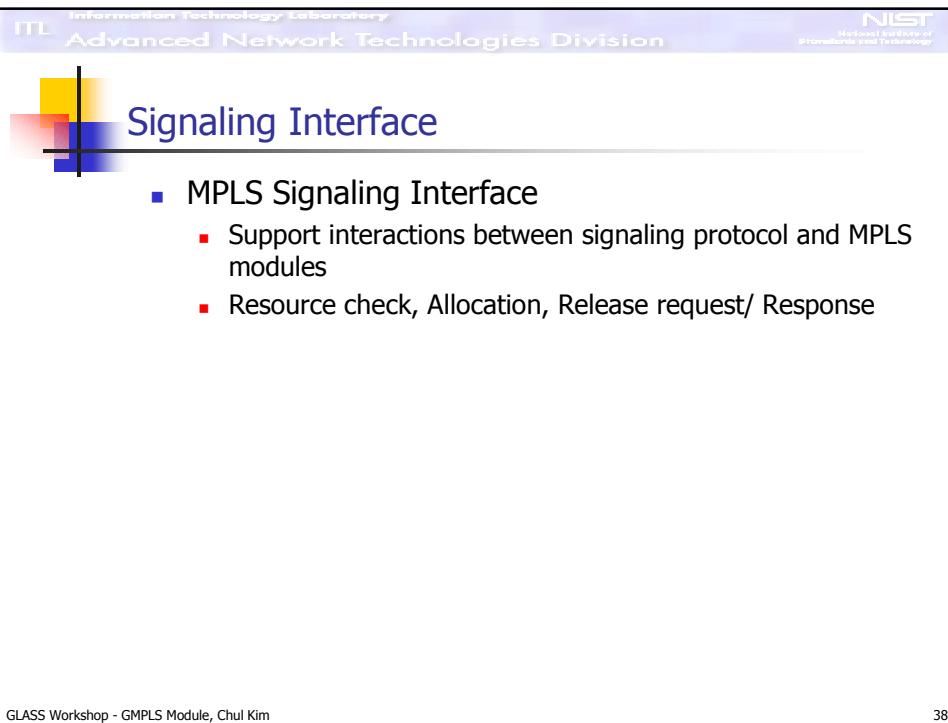
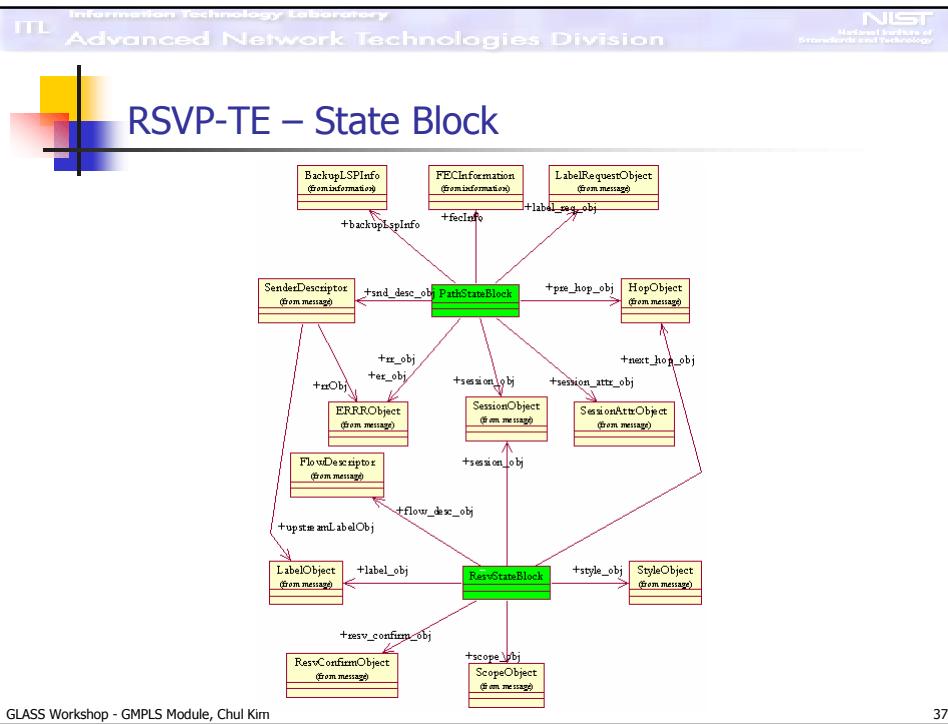
classDiagram
    class PeerLSRInfo {
        +peerSigProtocol
    }
    class SignalingProtocol {
        +sigProtocol
    }
    class PeerLSRMgmt {
        +peerLSRMgmt
    }
    class S_CRLDP {
        +peerLSRInfo
        +peerLSRMgmt
    }
    class CRLDPControlBlock {
        +localCldp
        +prevNodeCldp
        +nextNodeCldp
    }

    PeerLSRInfo "0..1" --> "1" SignalingProtocol : +peerSigProtocol
    SignalingProtocol "1" --> "1" S_CRLDP : +sigProtocol
    PeerLSRInfo "0..1" --> "1" PeerLSRMgmt : +peerLSRInfo
    PeerLSRMgmt "1" --> "1" S_CRLDP : +peerLSRMgmt
    S_CRLDP "1" --> "1..2" CRLDPControlBlock : +peerLSRInfo
    S_CRLDP "1" --> "1..2" CRLDPControlBlock : +peerLSRMgmt
  
```

GLASS Workshop - GMPLS Module, Chul Kim

34





MPLS Interface - I

- MPLS Interface

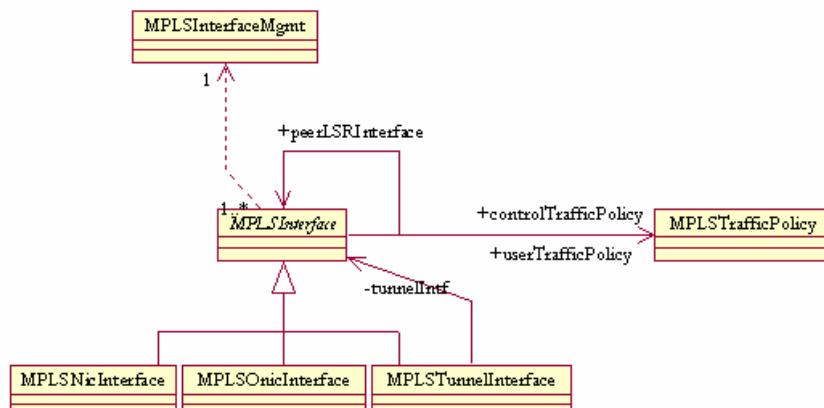
- Support data-link layer functions
- Queuing/scheduling
- Three type interfaces
 - NIC, ONIC, Tunnel

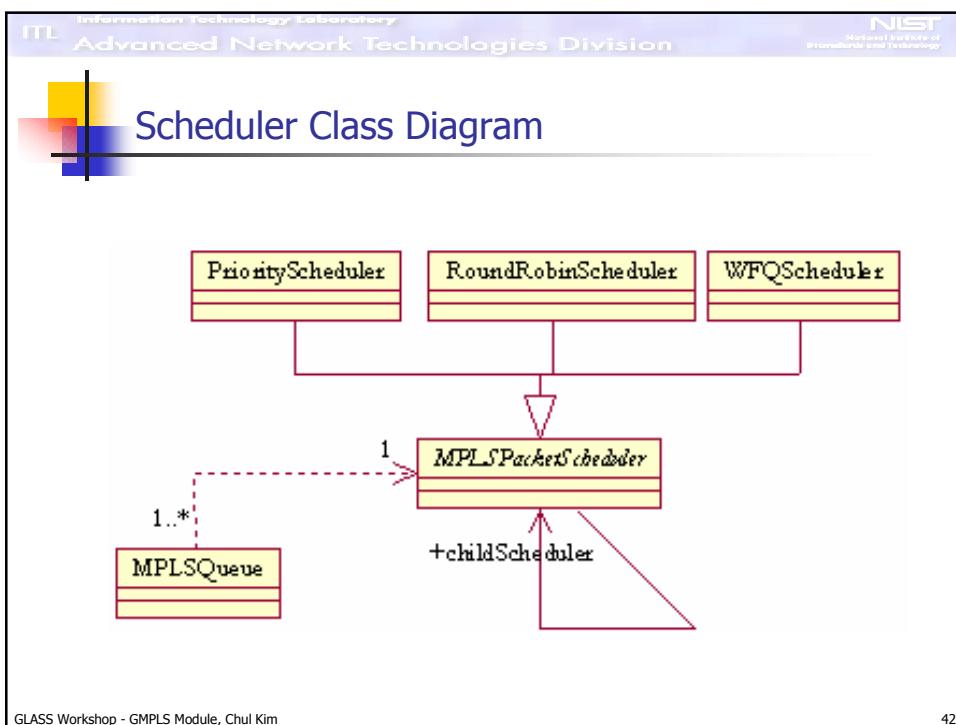
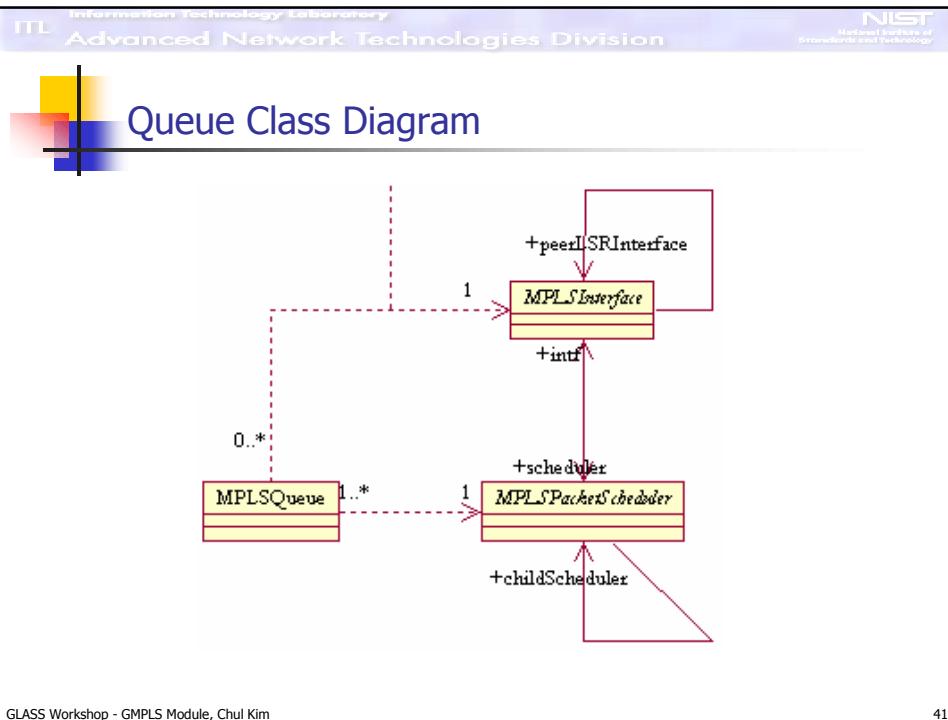
- Implementation

- MPLSInterfaceMgmt module
 - Create MPLSInterface according to the Host configuration
- MPLSInterface module
 - Perform the Interface functionality
 - Push, queuing, scheduling

MPLS Interface - II

- Class Diagram





ITL Information Technology Laboratory
Advanced Network Technologies Division

NIST National Institute of Standards and Technology

- Packet Scheduling
 - Support Hybrid packet scheduling

```

graph LR
    P1[Priority] --> S1[Rate-based scheduler]
    P2[Priority] --> S1
    P3[Priority] --> S1
    P4[Priority] --> S1
    P5[Priority] --> S1
    P6[Priority] --> S1
    S1 --> PS[Priority Scheduler]
    PS --> O[Priority]
  
```

GLASS Workshop - GMPLS Module, Chul Kim

43

ITL Information Technology Laboratory
Advanced Network Technologies Division

NIST National Institute of Standards and Technology

- Forwarding Table and Forwarding

- Class Diagram

```

classDiagram
    NHLFE "1..*" -->|dashed| ForwardingInformation
    ForwardingInformation "1" -->|dashed| ILMEntry
    ForwardingInformation "1" -->|dashed| FTN
    ForwardingInformation "1" -->|dashed| tunnel_entry
    ILMEntry "0..*" -->|dashed|> 1..* MPLSForwardingTable
    FTN "0..*" -->|dashed|> 1..* MPLSForwardingTable
    tunnel_entry "0..*" -->|dashed|> 1..* MPLSForwardingTable
  
```

GLASS Workshop - GMPLS Module, Chul Kim

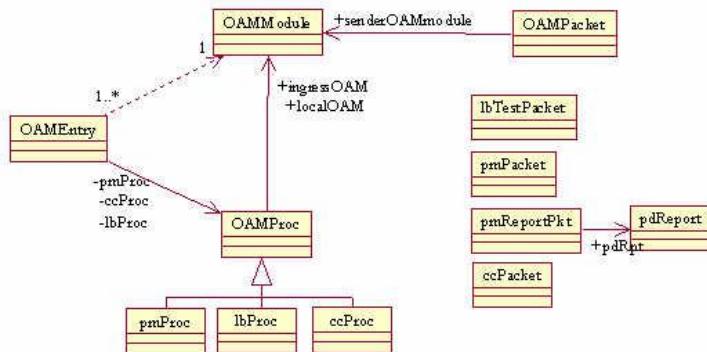
44

Management Modules

- TE Agent
 - Support LSP setup information
 - Basic fault restoration functions
 - OAM module installation
- OAM
 - Basic OAM function
 - Continuity check
 - Loopback
 - Performance Degradation alert
- Fault Management
 - Support Fault notification function through the TE Agent

OAM Module

- Classify OAM packets according to OAM procedures
- Classify OAM procedures





GMPLS Monitor infrastructures



ITL Information Technology Laboratory
Advanced Network Technologies Division

NIST
National Institute of
Standards and Technology

GMPLS Monitor

- Support four types monitors
 - LSP monitor
 - Queue monitor
 - NIC monitor
 - OAM performance Monitor
 - When OAM performance monitor is activated
- Based on SSFNet monitor infrastructure
 - One result file

GLASS Workshop - GMPLS Module, Chul Kim

48

ITL Information Technology Laboratory
Advanced Network Technologies Division

NIST National Institute of Standards and Technology



LSP Monitors

- Monitor parameters

Location	Ingress LSR	Egress LSR
Monitored Parameters	<ul style="list-style-type: none"> - Utilization(%) - Packet Loss Ratio (by the Traffic Policy) - Packet Loss Bytes 	<ul style="list-style-type: none"> - End to end delay (sec) - Average End to end delay (sec) - Jitter (sec) - Throughput (bps) - Minimum Delay - Maximum Delay

GLASS Workshop - GMPLS Module, Chul Kim

49

ITL Information Technology Laboratory
Advanced Network Technologies Division

NIST National Institute of Standards and Technology



Queue Monitor

- Monitor each queue at MPLS Interface
- One queue per one LSP
- Monitored parameters
 - Incoming packet bits/bytes/count
 - Outgoing packet bits/bytes/count
 - Drop packet bits/bytes/count
 - Average queuing delay
 - Queue length bits/bytes

GLASS Workshop - GMPLS Module, Chul Kim

50

ITL Information Technology Laboratory
Advanced Network Technologies Division

NIST
National Institute of
Standards and Technology



NIC Monitor

- Monitors incoming / outgoing packet

GLASS Workshop - GMPLS Module, Chul Kim

51

ITL Information Technology Laboratory
Advanced Network Technologies Division

NIST
National Institute of
Standards and Technology

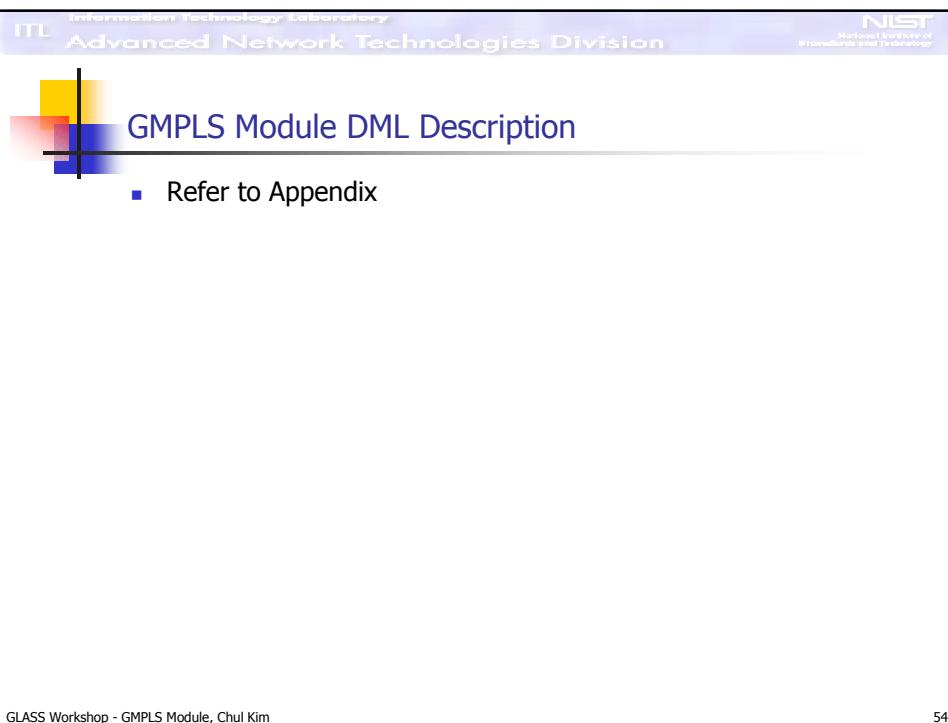
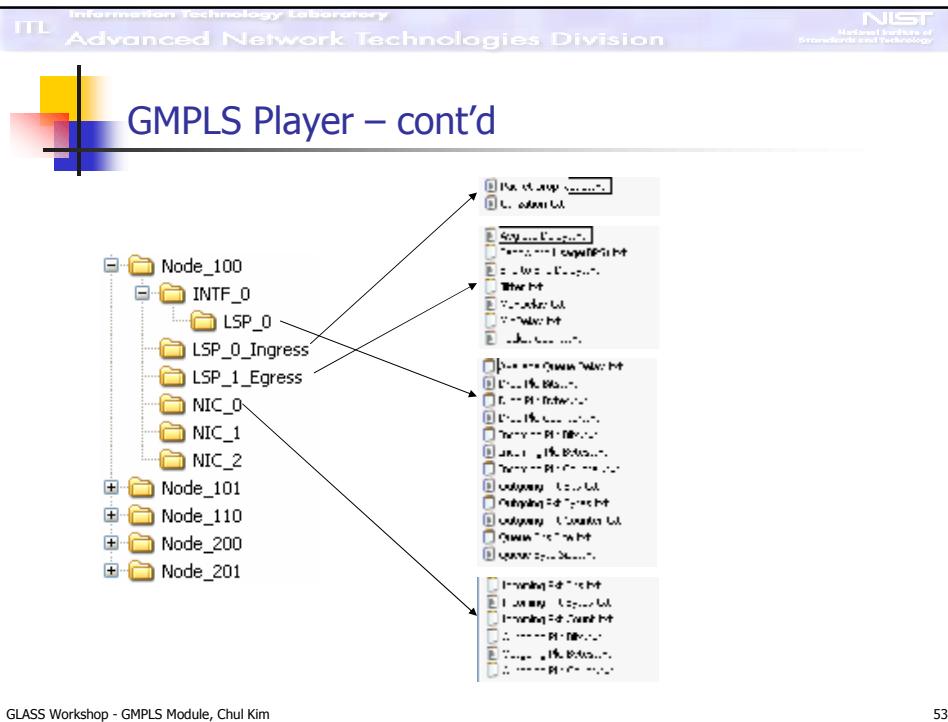


GMPLS player

- Support four players according to each monitors
- Generate the result as directory

GLASS Workshop - GMPLS Module, Chul Kim

52





Appendix



LSP Type

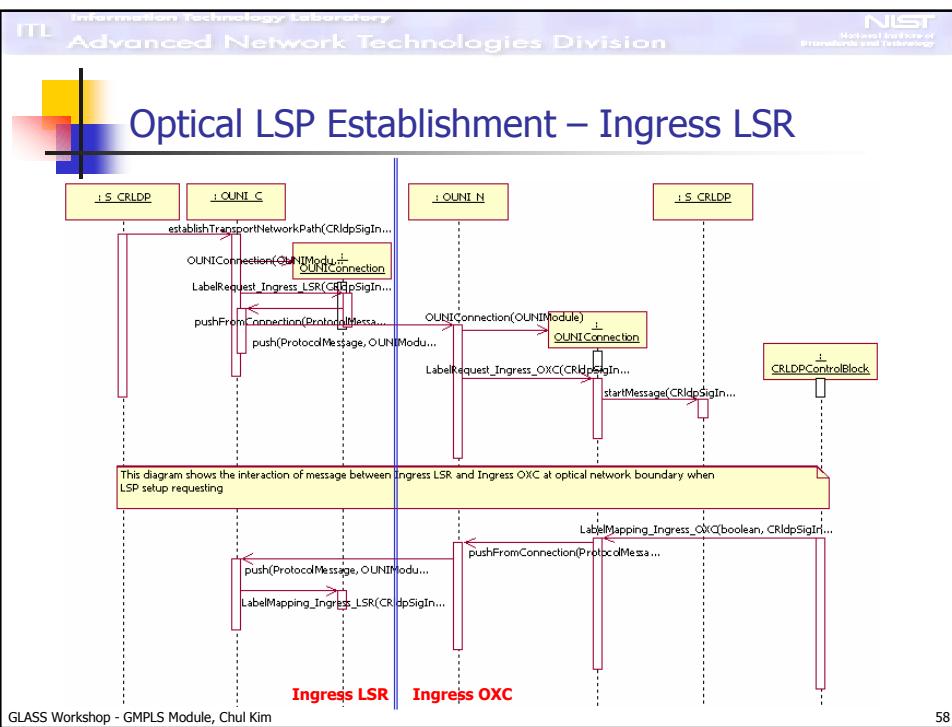
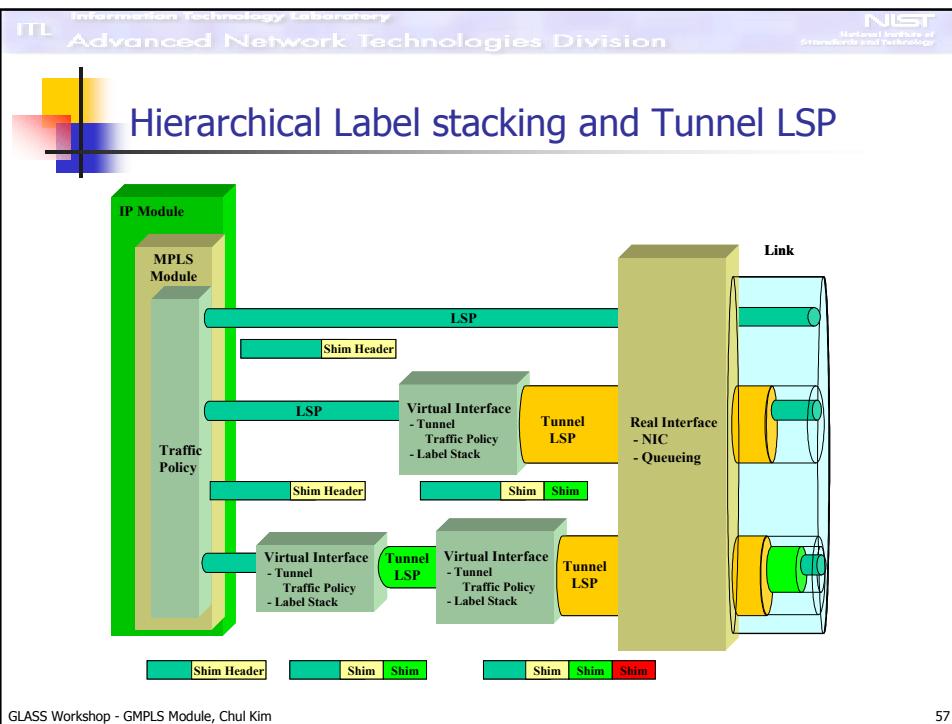
- Normal LSP
- Tunnel LSP
 - Support Tunneling
- Optical LSP
 - Similar to Tunnel LSP except that this LSP go through the Optical Network domain
- Backup LSP
 - Used to establish backup LSP

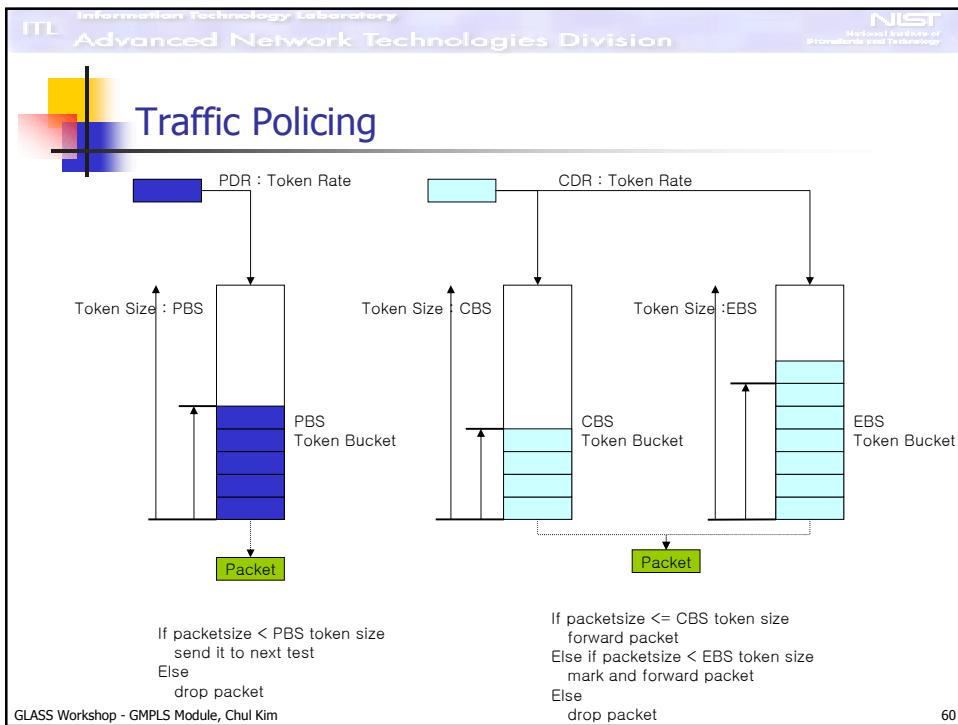
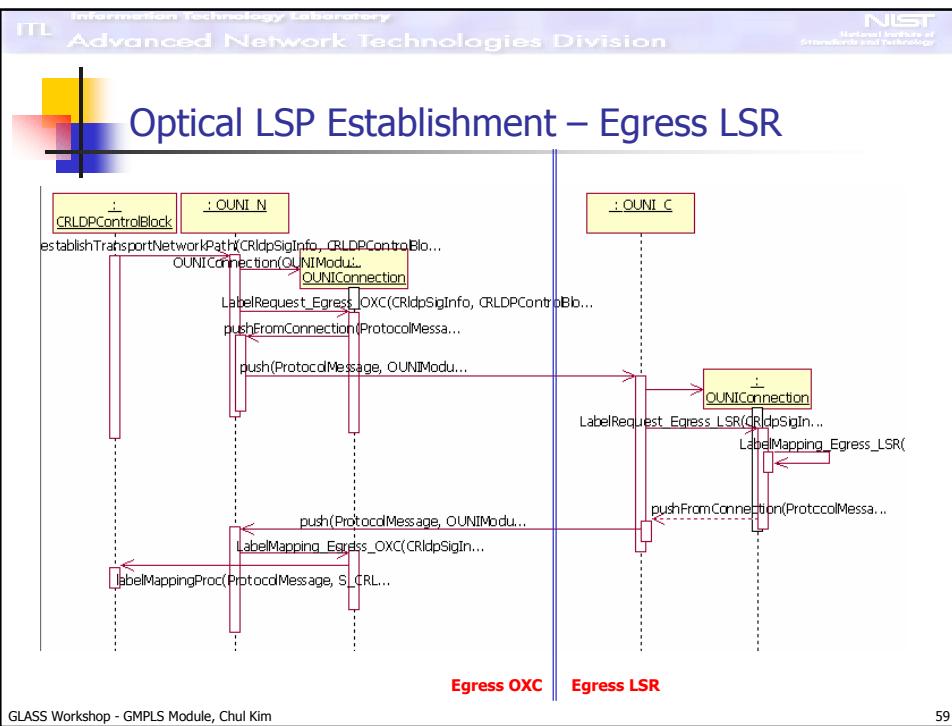
ITL Information Technology Laboratory
Advanced Network Technologies Division

NIST National Institute of Standards and Technology

GLASS Workshop - GMPLS Module, Chul Kim

56







ITL Information Technology Laboratory
Advanced Network Technologies Division

NIST
 National Institute of
 Standards and Technology

CR-LDP vs. RSVP-TE

Issues	CR-LDP	RSVP-TE
Major supporter	Nortel	Cisco
Connection State management	Hard state (no periodic update after connection establishment)	Soft state (periodic update after connection establishment)
TE extensions	Support constraint-based routing and TE extensions	Support constraint-based routing and TE extensions
Additional functionality		RSVP-TE based fault managements have been proposed in IETF
General Remark		Received more supports from the IETF meeting at Yokohama

GLASS Workshop - GMPLS Module, Chul Kim

61



GMPLS Simulation Examples

ITL Information Technology Laboratory
Advanced Network Technologies Division

NIST National Institute of Standards and Technology

Example 01

- Basic MPLS LSR Configuration
- LSP Configuration

The diagram shows a network topology with two hosts (300 and 400) connected to a sequence of four nodes: LER 100, LSR 200, LSR 201, and LER 101. The connections between LER 100 and LSR 200, and between LSR 201 and LER 101, are highlighted with dashed green lines labeled 'LSP 0'. The connections between LSR 200 and LSR 201 are highlighted with dashed yellow lines labeled 'LSP 1'.

GLASS Workshop - GMPLS Module, Chul Kim

63

ITL Information Technology Laboratory
Advanced Network Technologies Division

NIST National Institute of Standards and Technology

Example 02

- Multi-host Configuration

The diagram shows a network topology with three hosts (300, 400, and 401) connected to a sequence of five nodes: LER 100, LSR 200, LSR 201, LER 101, and LER 401. The connections between LER 100 and LSR 200, and between LSR 201 and LER 101, are highlighted with dashed green lines labeled 'LSP 0'. The connection between LSR 200 and LSR 201 is highlighted with a dashed yellow line labeled 'LSP 1'. Host 300 is connected to LER 100, and host 401 is connected to LER 101.

GLASS Workshop - GMPLS Module, Chul Kim

64

ITL Information Technology Laboratory
Advanced Network Technologies Division

NIST National Institute of Standards and Technology

Example 03

- Tunnel LSP Configuration

The diagram illustrates a Tunnel LSP configuration. It shows a network topology with hosts 300 and 400 connected to Left Edge Routers (LER). These LERs are connected via a Tunnel LSP (blue tube) to two Label Switch Routers (LSR). The LSRs are also connected to Right Edge Routers (LER), which are connected to hosts 401 and 400. A separate Normal LSP is shown connecting host 401 to host 400.

GLASS Workshop - GMPLS Module, Chul Kim

65

ITL Information Technology Laboratory
Advanced Network Technologies Division

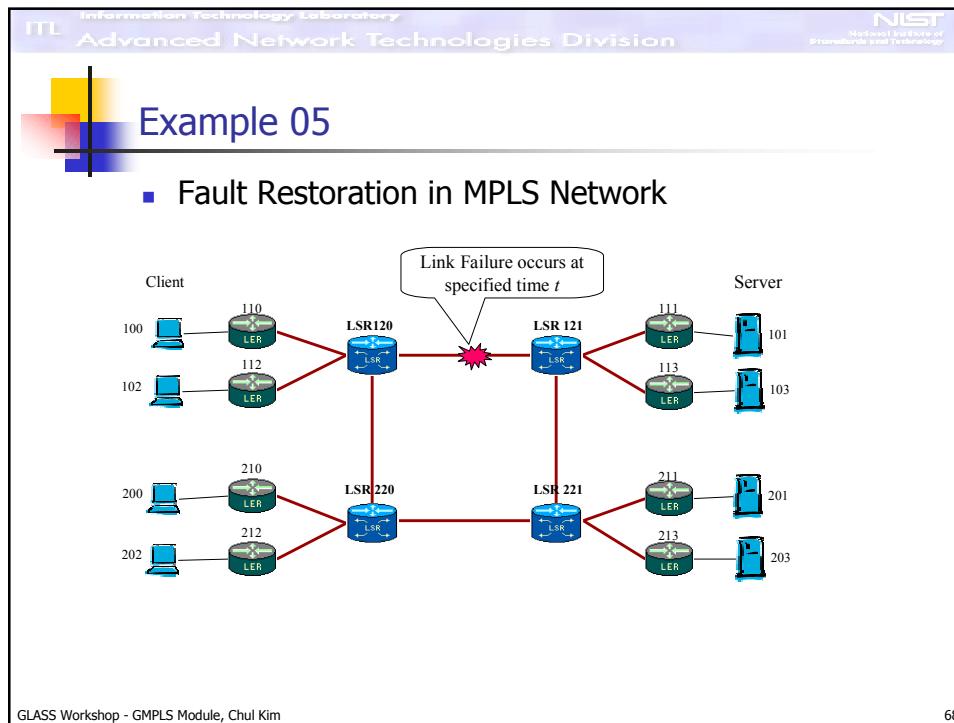
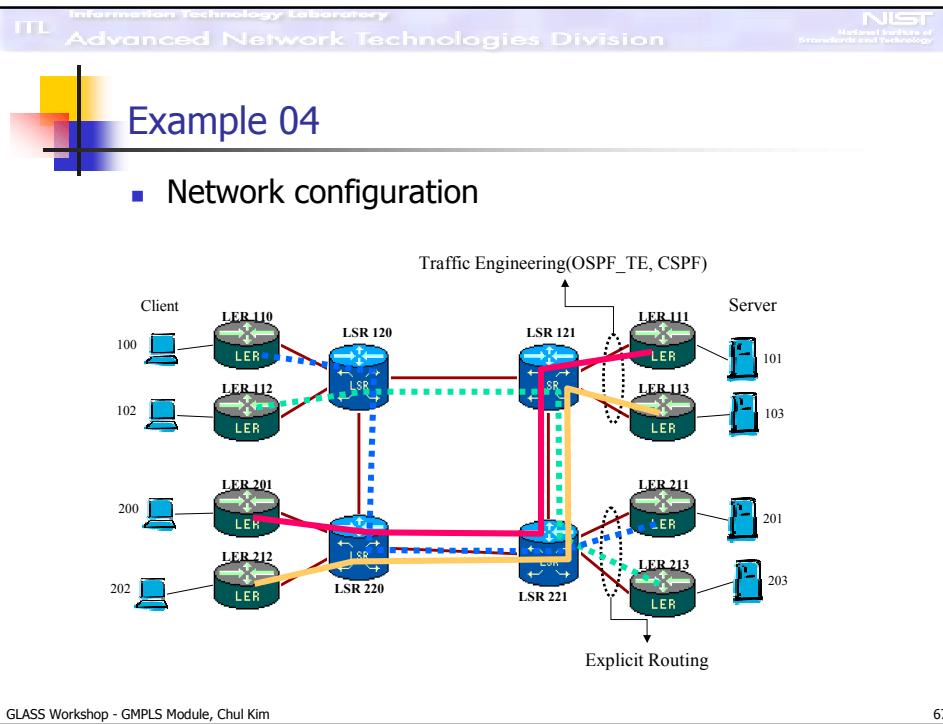
NIST National Institute of Standards and Technology

Example 04

- MPLS Traffic Engineering
 - Constraint-based Routing with OSPF-TE
 - Explicit Routing

GLASS Workshop - GMPLS Module, Chul Kim

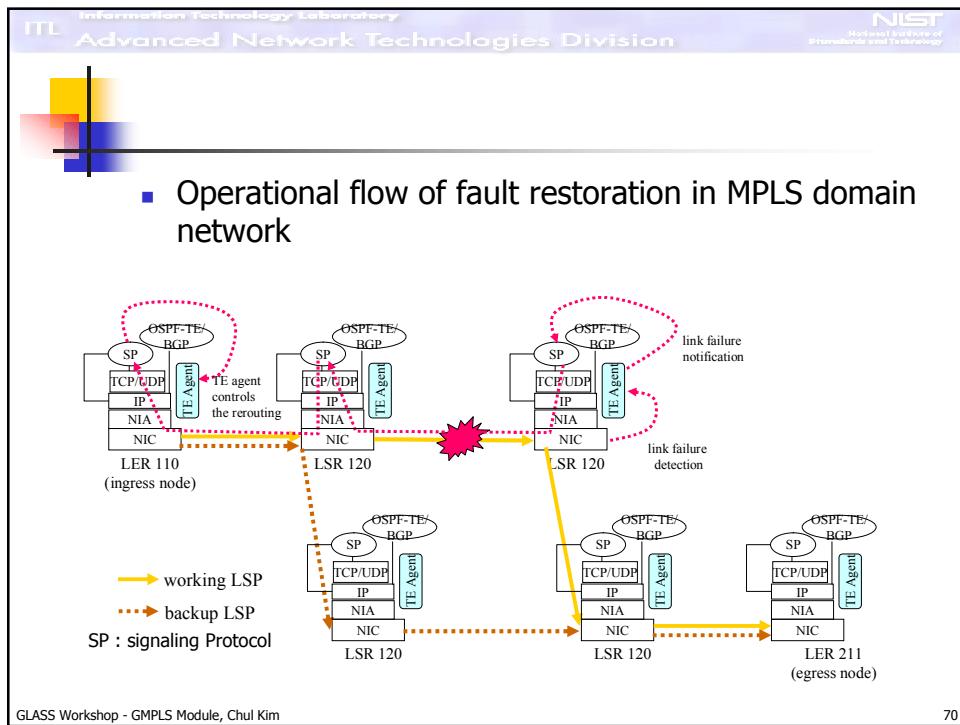
66



ITL Information Technology Laboratory Advanced Network Technologies Division NIST National Institute of Standards and Technology

- 1:1 backup LSP establishment
 - link disjoint from working LSP
- Link failure restoration procedure
 - 1:1 backup LSP is prepared for the working LSP according to the LSP fault restoration policy
 - Link failure occurs at specified time t (DML file)
 - NIC detects link failure
 - NIC informs link failure to TE-agent
 - TE-agent requests signaling protocol to send link-failure message to ingress node and egress node of the related LSP
 - Signaling protocol sends link-failure message to both ingress and egress nodes; these messages are forward by intermediate LSRs
 - ingress node (LER) checks the availability of backup LSP for the erred working LSP, and if available reroutes packets to the backup path
 - ingress node (LER) sends LSP release signaling message through the route of the erred LSP

GLASS Workshop - GMPLS Module, Chul Kim 69



ITL Information Technology Laboratory
Advanced Network Technologies Division

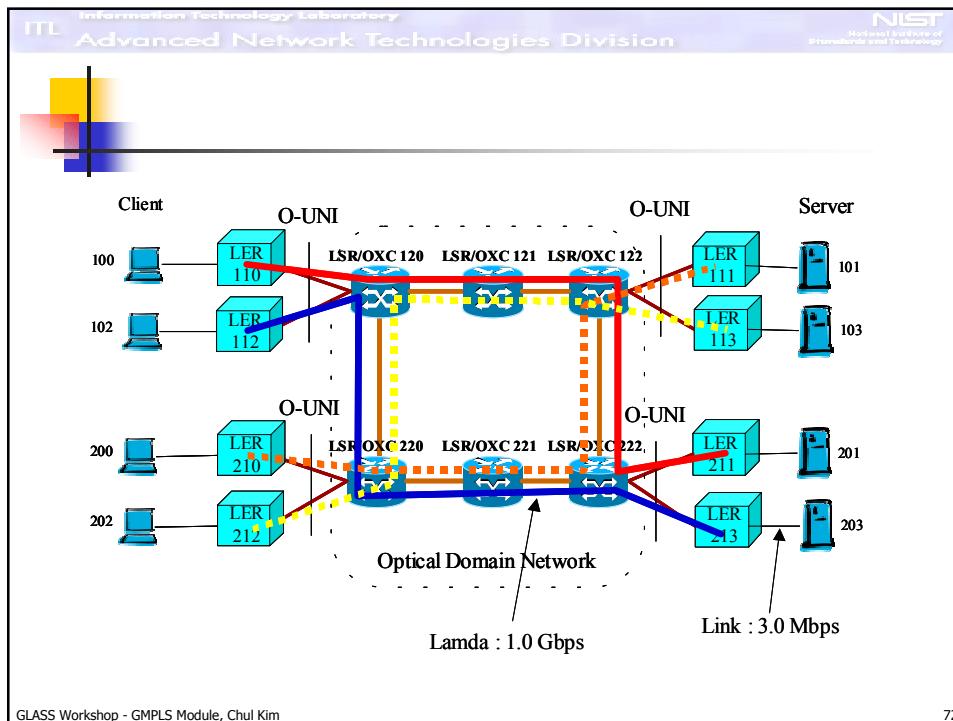
NIST National Institute of Standards and Technology

Example 06

- Optical RWA with OSPF-TE
 - Optical UNI(O-UNI)
 - Optical domain routing with OSPF-TE
 - GMPLS Signaling (CR-LDP, RSVP-TE) for Optical domain network and Wavelength assignment
 - MPLS Tunnel LSP through optical domain

GLASS Workshop - GMPLS Module, Chul Kim

71



Example 07

- Multiple LSPs on an optical WDM Link

